Mobile GIS

Mapping California's Aquatic Weed Control

California officials are using mobile GIS to monitor how herbicides that slow the growth of aquatic weeds may impact native species and water quality.

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Every year, millions of people use California's 1,300 miles of coastline and 3,000 miles of inland waterways to fish, cultivate crops, conduct shipping, and enjoy recreational activities. Maintaining water quality and protecting native species found throughout these regions is an ongoing challenge for state field crews, especially with California's current austere economic atmosphere.

Add to that the proliferation of invasive non-native vegetation, and the task calls for extremely creative natural resource-management solutions. That's why the California Department of Boating and Waterways (CDBW) — whose mission is to provide for safe and convenient public access to California's navigable waterways — incorporated spatial technologies into its Aquatic Weed Control Program. Specifically, CDBW is using enterprise GIS, georeferenced imagery, mobile GIS/GPS, and related technologies to manage the waterways and adjacent environments as well as to monitor the impact of herbicide applications in the project area.

Putting a Chokehold on Pests

Two of the more troublesome aquatic pests found in California's populated waterway regions are *Egeria densa* (Brazilian elodea), a popular aquarium plant, and *Eichhornia crassipes* (water hyacinth), which is used in private ponds. Both of these species are found in the Sacramento–San Joaquin Delta and its tributaries. Each of them obstruct navigation channels and waterways, slow water flows, destroy natural ecosystems, and clog agricultural irrigation pumps and systems. They also

Above: A worker removes Brazilian elodea from trash racks at the Skinner Fish Facility. Inset: An Environmental Impact Report was completed in March 2000 to identify sites throughout California's Delta area that could benefit from herbicide application. The 368 areas are highlighted in blue.

interfere with a variety of recreational activities and, as a result, have a negative impact on waterway businesses, including marinas.

Brazilian elodea is also affecting California's State Water Project, which manages the transfer of water from the northern portion of the state to the more arid southern regions. Elodea mats accumulate on the trash racks at fish screens and other facilities and compromise capacity at nearby pumping plants. Between December 2003 and January 2004, plants have lost an estimated 60,000 acre-feet of pumping capacity because of the proliferation of these aquatic weeds (see Figure 1).

In compliance with legislative mandates, CDBW applies herbicides to diminish the growth of these pests, but endangered species mitigation is limiting the program's operation throughout most of the region to just summer and fall (July to October). As a result, CDBW is currently monitoring how application of herbicides in the delta region impacts waterways and the endangered species that inhabit them. Once the research is completed, CDBW hopes to show that earlier application of federal- and state-approved herbicides does not negatively impact protected species. Keeping these programs on track, however, has required the department to adopt new technologies that enable fast and easy tracking of data in the field.

Courtesy of Richard Gage, Department of Water Resources, Delta Field Division

Automated Monitoring

The department's herbicide-related research programs require meticulous reporting and analysis of herbicide application data, monitoring data, and laboratory results. During the beginning stages of the program, field personnel collected GPS coordinates using recreational grade units with an optimum accuracy of 3–5 meters. These coordinates and corresponding treatment data were recorded on daily paper reports. Data were then keyed into a computer spreadsheet program. This entire process lent itself to human error, as the possibility of illegible handwriting and transposition of numeric data existed. In addition, without a centralized location to store and extract the necessary information, data analysis and reporting were time-consuming and complex.

Today, CDBW uses a new automated method that incorporates geospatial technologies and centralized data storage, distribution, and analysis capabilities to complete its herbicide application research. Technologies for this enterprise system include GPS and field computers, mobile and desktop GIS software and hardware platforms, enterprise database management software, and Web-based map servers. The solution facilitates accurate collection of GPS coordinate information, requires limited training, and offers versatility for future expansion. Selection

PROJECT METADATA

Location: California's Sacramento–San Joaquin Delta

Mission: Monitor how applications of herbicides in the region impact waterways and endangered species

Innovative Solutions: Enterprise data workflow for mobile GIS application and use of sensors integrated with GPS to obtain georeferenced water-quality samples

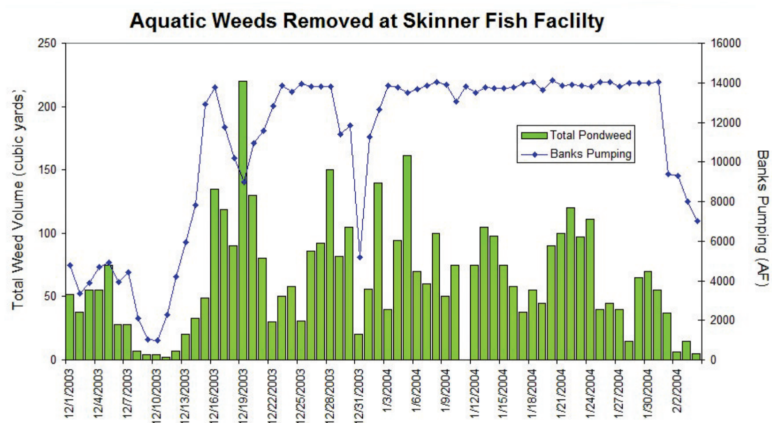
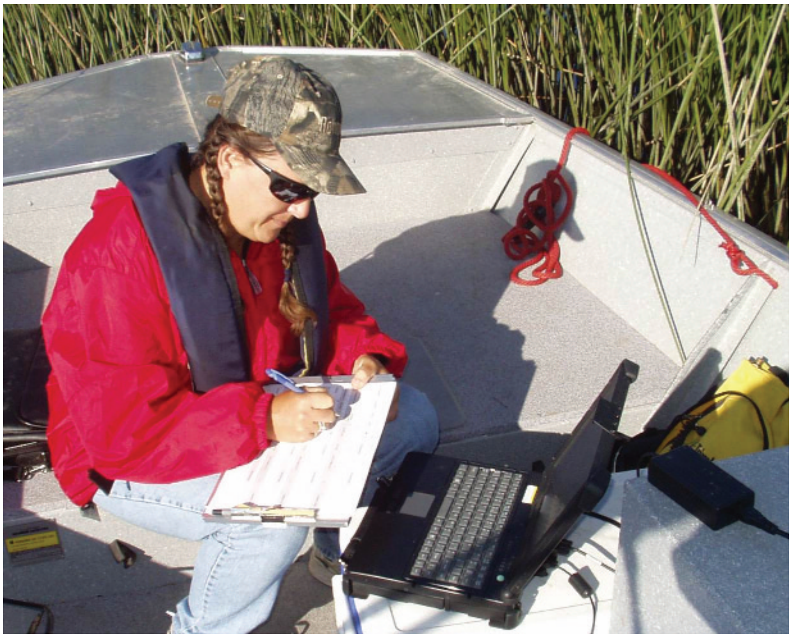


Figure 1. This chart illustrates the relationship between the growth of *Egeria densa* and other pests on trash racks at the Skinner Fish Facility and its impact on pumping capacity at the nearby Banks Pumping Plant.

Chart courtesy of Jeffrey Janik, staff environmental scientist, Department of Water Resources

Courtesy of California Department of Boating and Waterways

Field Crew Supervisor Tim Artz demonstrates the complex root structure of an invasive water hyacinth during crew training.



Photos courtesy of California Department of Boating and Waterways

Field crews have been instrumental in designing and implementing the data collection process. Environmental Scientist Julie Owen records water-quality data in the field (above). Surrounded by dense aquatic vegetation (right), a field crew applies an herbicide.

of specific components, however, took a significant amount of time, planning, and research.

Technology Challenges. Selecting the appropriate hardware to meet the needs of field data collectors proved most challenging. The department considered using a handheld PDA combined with an attached or handheld GPS, but the system provided limited capacity for data storage and inadequate screen space for location-based images. CDBW also considered using a GPS unit with submeter accuracy and a handheld Windows CE device, but field crews still needed a larger screen size and powerful hard drive and processor to enable them to view digital ortho quarter quads and satellite imagery in the field.

In the end, CDBW selected Tablet PCs because of their light weight, moderate cost, and fast processing capabilities. The new field data collection system consists of a GPS system that offers real-time differential GPS (corrections come from a network of U.S. Coast Guard GPS beacons in the area) and provides submeter horizontal accuracy and a Tablet PC loaded with GIS software. Subcontractors use a mix of hardware that consists of a Windows CE device integrated with a GPS unit. Although CDBW uses a range of hardware options for fieldwork, software continuity exists because all run on the same GIS platform.

Data Dilemmas. CDBW also had various data-related hurdles to overcome. CDBW crews collect many different types of data, including water-quality parameters, botany surveys, and species surveys. All of the data must be organized in a logical way to support CDBW's daily operations. As a result, CDBW designed a data repository that was flexible enough to allow for disparate data to be stored in the same location. An easy-to-use interface also enabled the generation of monthly, semiannual, and annual reports.

In all, three geodatabases were created in a structured query language (SQL) data repository. These include

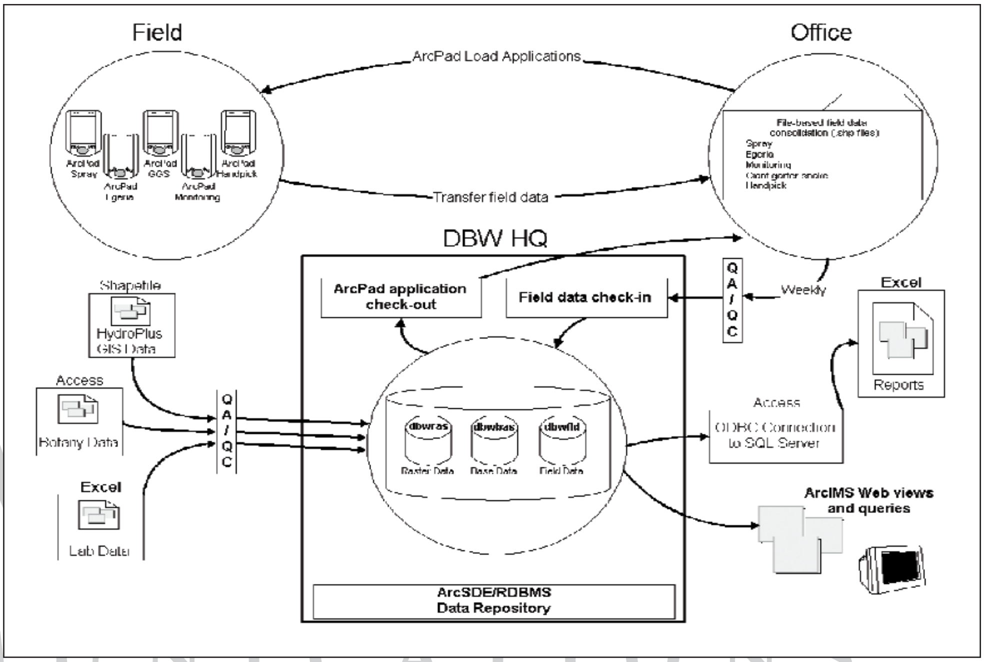
- Field data — This database is for storing field data that are specific only to the Aquatic Weed Control Program
- Raster data — This includes imagery used to support the aquatic weeds program as well as other CDBW initiatives
- Base data — This includes other datasets that are used as background layers for map production, such as county boundaries and hydrology layers.

All spatial data associated with the weed control program are incorporated into one of these three databases. Information collected in the field is stored in the field geodatabase, and the other two databases are used for background and analysis. This design offers many benefits, including the ease with which IT staff can set up permissions and back up procedures.

Building a Business Process

The Aquatic Weed Control Program requires the documentation of a variety of steps, including herbicide application, environmental monitoring, field crew coordination, and field data collection. Herbicide application involves following the stringent Environmental Protection Agency labeling requirements. Individual application prescriptions are devised by a California-licensed pesticide-control advisor, and CDBW staff must be trained and licensed to apply herbicide. Detailed reports must include information about application amounts and chemicals remaining after each application. Because of this program's complexity, CDBW has defined a business process that outlines each step in the program. CDBW's GIS analyst serves as the data gatekeeper and controls data flow from the data repository to the field and vice versa (see Figure 2).

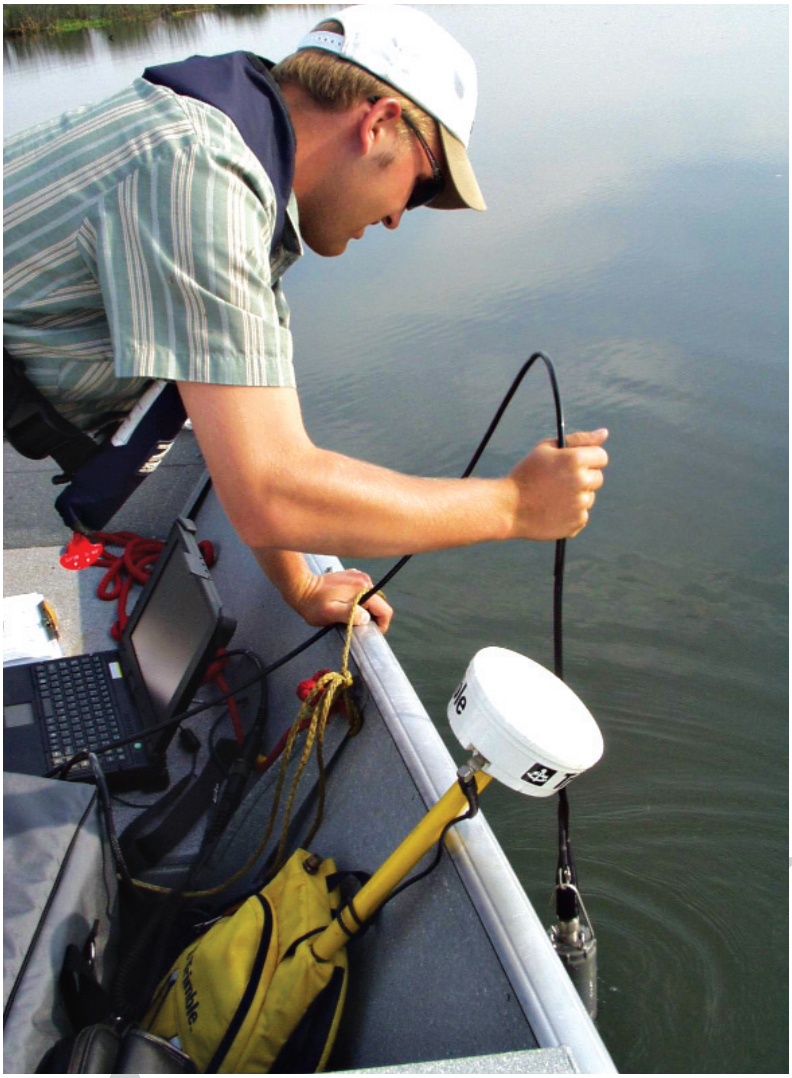
Step 1: Data Conversion. In preparation for field data collection, "clean" data are checked out of the repository using GIS software that allows users to select specific feature datasets and classes for use with the mobile GIS and field mapping software. During checkout, geodatabase-formatted data are converted to a shapefile, and field data collection forms are cre-



Courtesy of VESTRA Resources

Figure 2. CDBW designed a business process that controls data flow between the office and the field.

CIRCLE 12



Crew member Seth Lyman obtains georeferenced measurements from water-quality sensors. The data are automatically integrated to the mobile GIS.

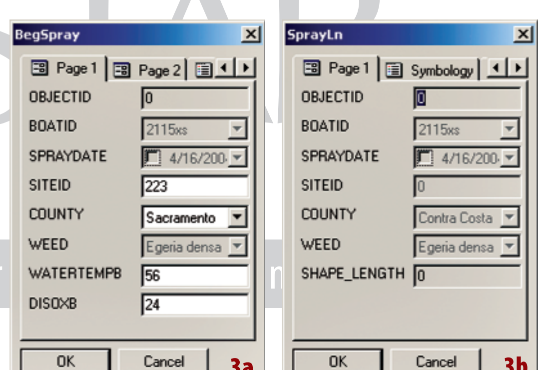
ated on the fly. Because CDBW application crews are not concerned with navigating back to an exact location, only the data layer schema (the format of the geodatabase) is checked out, resulting in shapefiles with no features. This allows field crews to use field data collection forms that model how the geodatabase was defined.

Initially, CDBW used generic field data collection forms, but in 2004 the department began customizing its forms using a developer's kit designed for the mobile GIS software. Now, efficiencies can be coded into the forms and functionality — such as auto population of unique identifications, summing up of chemicals used in a day, and guidelines for following the business process — are also built into the forms. Data and forms are then loaded on the tablet PCs and other Windows CE hardware.

Step 2: Field Work. The business process also outlines specific steps that crews take in preparation for chemical application. For example, before herbicides are ever applied, crews must obtain the GPS location of their boats. Crew members must also note the temperature and dissolved oxygen level of the water, the direction and speed of the wind, and the estimated size of the treatment area.

To collect these data, CDBW environmental scientists use sensors — such as a multiparameter water quality probe — that feed water-quality data directly into the field computer by way of a PC COM port. Measurements from such devices are integrated directly to the mobile GIS software to record location-specific water-quality data in shapefile format. In other cases, while acquiring GPS positions, application crews measure conditions such as wind speed and water temperature and enter them into the tablet PC or other system using a keyboard or pen stylus. The water-quality sensors are linked to the computer by way of a cable that connects to the PC COM port, and scientists georeference environmental readings using water-quality parameters, such as dissolved oxygen and acidity (Ph), which come from the probe. Documentation must also include reporting the chemicals used, spray dates, and names of crew members on the boat. All of this information is entered into the mobile GIS software using a pick-list contained in pull-down menus.

During chemical application, field crews map the treatment locations as lines using submeter GPS. The site ID, weed treated, and length of the treatment line are shown as features in the mobile software (see Figures 3a and 3b). The location at which spraying is



Courtesy of VESTRA Resources

Figure 3a and 3b. Field crews use pull-down menus in the mobile application to record metadata about their spraying activities, including when and where they began (**3a**) and the spray path (**3b**).

stopped is also acquired via GPS, and other information, including the amount of each chemical used, is also noted. After chemical application is completed, crew members unload the boats. The mobile GIS/field mapping software provides totals of chemicals used in that day's weed-control process.

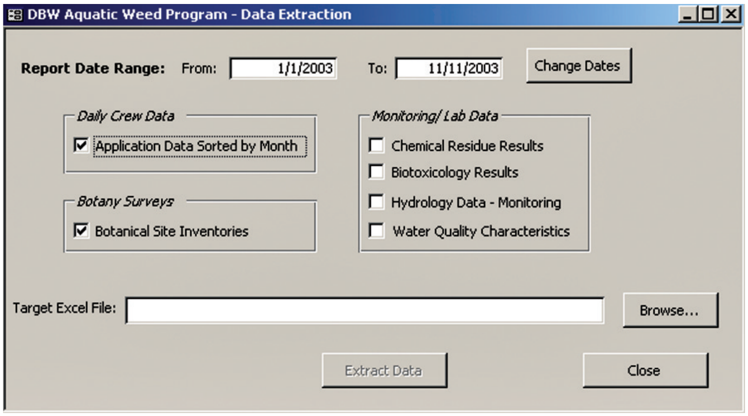
While in the field, crews also document observations related to endangered species and plants. Species such as the giant garter snake, chinook salmon, and the valley elderberry longhorn beetle are documented and accounted for in the mobile GIS software. Application crews acquire GPS locations of these species and, if possible, they take a digital photo of the animal to take back to the office. Digital photos are stored on the digital camera, and the GPS position as well as the photo's identification (which is recorded by the camera) are acquired and logged.

Step 3: Back at the Office. Once the field equipment is brought back into the office, the same staff member who loaded the clean data onto the field computer transfers the field data to the desktop GIS for quality-assurance editing. Data are reviewed and edited for accuracy and loaded into the repository via a customized check-in tool. This tool allows large batches of field data to be checked in. Additionally, custom check-in software ensures that field data are automatically loaded into the proper geodatabase. A log that records the full name of each shapefile and any problems that occurred during data loading is also generated at this time.

Ultimately, all data are used to generate the monthly, semiannual, and annual reports that the department creates for the State Water Board and other government agencies. To facilitate report generation, CDBW uses database query forms that allow staff to acquire data specific to study sites, date ranges, and/or chemical applications for each report (see Figure 4). The queries operate on tables directly linked to the database. Users can also create their own customized queries to meet special reporting needs.

CDBW staff can also access an intranet that supports the weed control program. Depending on user privileges, employees can view relevant data and make maps of study sites that detail which chemicals were applied and when. To augment community planning and environmental conservation initiatives, CDBW plans to make some of this information publicly available in the future.

In this three-year process of using geospatial technology, CDBW has made great progress. This enterprise GIS deployment has improved CDBW's workflow process — from field data collection to environmental reporting — and has increased the efficiency of data collection and management.



Courtesy of VESTRA Resources

Figure 4. The extraction tool queries the GIS data repository to generate reports.

Manufacturers

CDBW's servers include a **Dell** PowerEdge with dual Xeon processors, 2.8-GHz memory, and 4 GB of RAM; and a Dell PowerEdge with a single Xeon processor, 2.8-GHz memory, and 2 GB of RAM. Both servers run **Microsoft** Windows 2000 Advanced Server. GIS software includes **ESRI**'s ArcMap for desktop mapping and GIS data editing, ArcIMS for Web-based GIS data sharing, ArcPad and Tablet PC for mobile GIS/GPS computing, and an ArcSDE data repository for centralized data management. Form customization is achieved using the ArcPad Developer's Kit. To load data into the repository, CDBW uses a customized ArcObjects tool that allows for multiple check-in of shapefiles. Field data collection hardware includes **Trimble**'s Pro XR GPS linked to a **Fujitsu** Stylistic ST4121 Tablet PC loaded with ArcPad 6.03. CDBW also uses a Trimble TSCe Windows CE device and a Trimble GeoXT. HydroPlus GIS, the ArcPad template that allows multiparameter water quality data to be acquired in shapefile format, was developed by **Electronic Data Solutions**. **VESTRA Resources** assisted with the planning and implementation of the integrated system. ⊕